Isotopic Data Sonification: Shale Hills Critical Zone Observatory

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ABSTRACT

Each precipitation event has a unique fingerprint. This fingerprint is recorded in the duration of the event and the isotopic composition of the rainfall, as a result of differing proportions of oxygen isotopes. The ratio of O^{16} to O^{18} is crucial in identifying origin and movement of water within the hydrologic cycle. In some investigated watersheds, as rainwater flows through the ecosystem, it is continually recorded by a series of in-ground instruments and examined as a means of understanding the responsiveness of the hydrologic system of a particular region. Sonification of the unique fingerprints of each storm as it passes through the hydrologic system offers an opportunity to sonically represent fluctuations in rainwater hydrology over an extended period of time, allowing for a deeper understanding of the hydrologic cycle of the region. Sonification of a watershed can include data for groundwater, stream water, and precipitation data. Transformation of the data into sound creates a uniquely informative representation of the data, removed from the constraints of static visualizations such as the line graph, and – if the datasets are long time duration – can provide a unique look at both single weather events and larger global warming patterns within a particular geographical region.

1. INTRODUCTION

This paper introduces techniques for exploring a large hydrologic database through the process of data sonification. The sonification of hydrologic data allows the end-user to explore multiple variables comprising the hydrologic dynamics of a region over an extended period of time. The present sonification project tracks variables pertaining to isotopic data, including groundwater, stream water, and precipitation, over a period of three years.

2. CRITICAL ZONE OBSERVATORIES

Critical Zone Observatories (CZOs) are natural laboratories for investigating the Earth's surface processes by monitoring streams, climate, and groundwater. Each CZO is instrumented for hydrogeochemical measurements of soil, canopy, and bedrock data. The U.S. CZO network grew to 9 observatories in 2013 [1] but CZOs are also developing worldwide. The CZO program is a collaborative effort to advance scientific understanding of multi-scale environmental interactions in the critical zone from bedrock to the atmospheric boundary layer [2]. Analysis of isotopic rainwater hydrology data at the critical zone observatories are crucial to our understanding of the hydrological health of each CZO-represented region throughout the United States.

3. ISOTOPE HYDROLOGY

Water molecules are composed of characteristic fingerprints that allow researchers to identify the origins and movements of the water through the hydrologic cycle. These molecules are composed of two oxygen isotopes, oxygen-16 (O^{16}) and oxygen-18 (O^{18}). O^{16}, the lighter of the two isotopes, evaporates at a faster rate. As a result, water that has been exposed to evaporation for a longer period of time contains a greater relative quantity of O^{18}. The ratio of O^{16} to O^{18} provides scientific information on the dynamics of hydrologic flow throughout a given region as well as information about the provenance of water during storm events [3]. Instruments in place at the Susquehanna Shale Hills Critical Zone Observatory in central Pennsylvania collect continuous hydrologic data to create a representation of the region's hydrologic health.

4. SONIFICATION PROCEDURES

The sonification of the isotopic data was created using Supercollider (http://supercollider.sourceforge.net/), an environment and programming language for real-time audio synthesis and algorithmic composition [4]. Data collected by hydrologists were stored in tables and streamed through instruments designed in the Supercollider language to represent each variable. For groundwater, the variables were represented by the sound of dripping water. The droplet rate, variation, pitch, loudness, and stereo panning location were determined by the ratio of O^{16} to O^{18} in the groundwater data. As the O^{16}/O^{18} ratio increases, the rate, sound variation, pitch, and amplitude increase, and the panning location shifts outward toward the listener's periphery. Similarly, the stream water data were represented by a variation of the "babbling brook" Supercollider code, and O^{16}/O^{18} ratio was represented by the pitch, airiness, amplitude, and stereo panning location. Lastly, precipitation was represented by designed storm sounds, including rain and thunder. Ratios of O^{16}/O^{18} are represented by thunder (triggered after the ratio reaches an adjustable positive number), the duration of the thunder, the distance and amplitude of the rain and thunder, the graininess of the rain, and the stereo pan location. Creating multiple sonic characteristics for each variable provides a wider range of auditory feedback than would a simpler one-to-one pairing of sonic-to-data variables.

4.1. Sonic Instruments

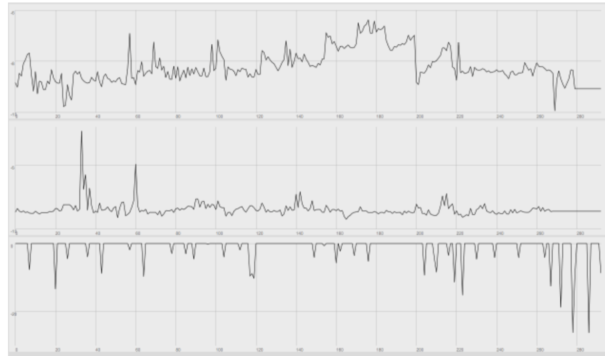
The instruments created in Supercollider were designed for flexible representation of dynamic data. Using multiple variables as a means of representing a single variable stream, sonification is designed to allow the listener to intuitively understand the dynamic fluctuations within the data without focusing on one variable.

```
(
SynthDef(\streamwater, {|freq=100, speed= 20 gate=1, amp=10, pan=0, mul=0.005, rq=0.03,
pitch1=500, pitch2=800, lpf1=14, lpf2=30, noise1=1, noise2=1, bubble1=1, bubble2,
coef=0.99|
    var src, src2, out, env;
    env=EnvGen.kr(Env.asr(0.01, 1), gate, doneAction:2);
    src=OnePole.ar(BrownNoise.ar(noise1), coef);
    src=RHPF.ar(src, LPF.ar(BrownNoise.ar(bubble1), lpf1)*pitch1 + 500, rq, mul);
    src2=OnePole.ar(BrownNoise.ar(noise2), coef);
    src2=RHPF.ar(src2, LPF.ar(BrownNoise.ar(bubble2), lpf2)*pitch2 + 1000, rq, mul);
    out=Mix.ar([src, src2]);
    out=GVerb.ar(out, 50, 0.4);
    out=Pan2.ar(src+src2, pan);
    Out.ar(0, out*env*amp*~masteramp)
}).add;
)
```

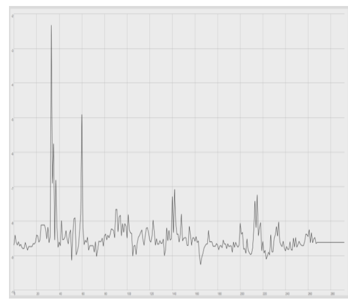
The instrument, or synthesis definition (SynthDef) above, is a variation of the 'babbling brook' example found in the Supercollider examples that come with the program. One instrument each was created for groundwater, stream water, and precipitation. The instrument above comprises Brown noise passed through a 'one pole', low pass and resonant high pass filter at two static cutoff frequencies. These sounds are mixed together (Mix.ar), then passed through a reverb, panned to two speakers, and output on those speakers. A master amplitude is defined at the outset. Variables included amount of Brownian motion, resonant high pass filter frequency, low pass filter frequency, pitch, rq (bandwidth/cutoff frequency), pan, and amplitude. Each variable is normalized between reasonable parameters in relation to the O^{16}/O^{18} ratio. The data are then run through a Task which iterates through the data one point at a time, and creates a corresponding sound. The speed at which the data are read can be adjusted to suit the listener, with faster speeds providing a more general trend in the data and slowest speeds representing point-by-point analysis.

5. ISOTOPE HYDROLOGY GRAPHS

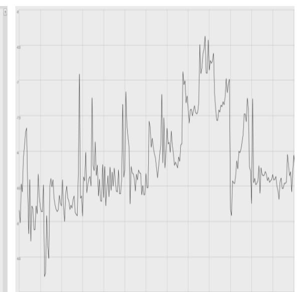
Figure 1 shows fluctuation in O^{16}/O^{18} ratios for groundwater, stream water, and precipitation respectively over the course of roughly 200 days throughout 2009.



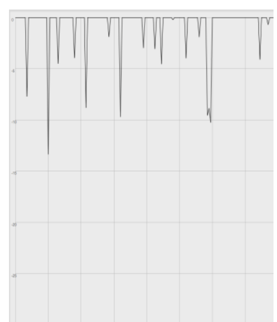
(a) All Variables 2009



(b) Groundwater 2009



(c) Stream water 2009



(d) Precipitation 2009

Figure 1: Fluctuation in O^{16}/O^{18} ratios (y axis) over about 200 days in 2009 (x axis).

6. SUMMARY

By comparing the sonic data between years and listening for indicators that identify seasonal changes, outliers within the dataset, and fluctuation patterns, geoscience researchers found the sonifications useful in providing an alternative representation of these large datasets.

7. ONGOING RESEARCH

Moving forward, sonifications are planned for other CZO locations within the United States and internationally in order to allow for cross-climate, cross-region examination. The work will be presented as an installation and concert at the end of the Spring 2014 semester, both as an art installation, which will include minimal visual elements, and as a concert piece featuring live musicians with an accompanying sonification.

8. REFERENCES

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